TECHNICAL BULLETIN NO. 101 APRIL 1977

Effect of Increasing Dietary Energy Levels on Performance of Laying Pullets Under Hawaii Temperature Conditions

A. L. PALAFOX

HAWAII AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF HAWAII

ABSTRACT

Two hundred fifty Single-Comb White Leghorn (Hy-Line) pullets raised in a subtropical climate were used to study the effect of different levels of energy (2576, 2682, 2788, 2894, and 3000 kilocalories of metabolizable energy per kilogram) (kcal ME/kg) in a 16 percent protein layer ration on egg production from 20 through 74 weeks of age.

Dietary energy level significantly affected body weight, egg weight, egg production, daily feed consumption, protein and energy consumption, and protein and energy consumption per egg produced. Pullet body weight increased and feed per egg decreased as dietary energy level increased. Daily consumption of feed and protein and feed and protein per egg decreased as the concentration of energy in the diet increased.

Seasonal temperature changes, even under the normally mild weather conditions of Hawaii, significantly affected egg production in this experiment. During the colder months of December to April (19.1–24.6°C), pullets fed the 2576 kcal ME/kg diet produced from 3.85 to 9.89 percent fewer eggs than those fed the 2682 to 3000 kcal ME/kg diets and significantly fewer eggs than those fed the 2682 and 2894 kcal ME/kg diets. Pullets fed the 2576 kcal ME/kg diet laid eggs at the rate of 57.91 percent compared to 65.18 percent and 67.80 percent, respectively, for those fed the 2682 and 2894 kcal ME/kg diets. During the warmer months of August to December (23.2–29.1°C) and April to August (21.1–28.2°C), no differences in egg numbers were apparent in the test groups.

For optimum overall efficiency, pullets fed the 2894 kcal ME/kg diet (energy to protein ratio, 181) were superior to those fed the 2576, 2682, 2788, and 3000 kcal ME/kg diets (energy to protein ratios, 161, 168, 174, and 188, respectively).

CONTENTS

Tables

THE AUTHOR

Anastacio L. Palafox is Associate Poultry Scientist, Hawaii Agricultural Experiment Station, and Associate Professor of Poultry Science, College of Tropical Agriculture, University of Hawaii.

Effect of Increasing Dietary Energy Levels on Performance of Laying Pullets Under Hawaii Temperature Conditions

A. L. PALAFOX

INTRODUCTION

The effect of dietary energy concentration in the nutrition of laying chickens has received considerable attention since the importance of higher energy rations for broilers was demonstrated by Scott et al. (1947). Brown (1964) reviewed the use of both high-energy diets and fats in such diets for poultry. His review revealed that limited information has been published on the use of high-energy diets for laying chickens raised under conditions outside the temperate zone.

Skinner et al. (1951), Lillie and Denton (1965), and Waring et al. (1968) reported that White Leghorn pullets gained in body weight with increase in dietary energy level. Jackson et al. (1969) found that successive increases in dietary energy from 1970 to 3530 kcal ME/kg resulted in body weight gain but that there was a decrease in weight of pullets fed the diet containing 4150 kcal ME/kg.

Feed intake of mature White Leghorn pullets decreased as the dietary energy level was increased (Waring et al., 1968; Jackson et al., 1969; Scott et al., 1969). Skinner et al. (1951) reported that egg production of White Leghorn pullets fed high-energy diets was superior to that of birds fed the control ration. Hill et al. (1956) found that high-energy diets supported the highest egg production during the months of cold weather, whereas all energy levels were equally effective during the rest of the year. However, Lillie and Denton (1965) reported that dietary energy did not significantly affect egg production of White Leghorn pullets.

Skinner et al. (1951), Lillie et al. (1952), and Hill et al. (1956) observed that increasing dietary energy reduced feed required per dozen eggs. Blamberg et al. (1964) and Jackson et al. (1969) found that White Leghorn pullets fed high-energy diets laid eggs that were significantly heavier than those of pullets fed the control ration. March and Biely (1963) reported that the addition of 0 to 10 percent tallow in the diet of White Leghorn chickens had no significant effect on mortality.

The objectives of this present experiment were to study (A) the effect of different levels of energy in a 16 percent protein layer ration on (1) body weight and gain, (2) mortality and sexual maturity, (3) egg weight, (4) egg production, (5) feed consumption and feed per egg, (6) protein consumption and protein per egg, and (7) energy consumption and energy per egg and (B) the effect of seasonal temperature on White Leghorn pullets raised under the subtropical conditions of Hawaii.

MATERIALS AND METHODS

Two-hundred fifty Single-Comb White Leghorn (Hy-Line) pullets were selected for general vigor and distributed at random into 25 cage groups, each consisting of 10 individually caged birds. At this time each bird was weighed. The test diets shown in Table 1 were fed during the 20 to 74 weeks-of-age test period. Each diet was fed to 5 replicate groups in a 5×5 latin square experimental design. Feed and water were provided ad libitum. Artificial lights were used to provide a constant day length of 14 hours. The birds were housed in a 9.81- × 31.11-m building with open sides enclosed by a 1.27- × 1.27-cm wire mesh cloth.

Daily minimum and maximum temperatures were obtained from the U.S. Weather Bureau Station No. 713 located 300 m from the laying house. Data were obtained on body weight, mortality and sex-

Table 1. Composition of experimental diets

Ingredient	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
	%	%	%	%	%
Cellulose	7.13	5.63	4.13	2.63	1.13
Tallow	0.00	1.50	3.00	4.50	6.00
Corn, ground yellow	59.93	59.93	59.93	59.93	59.93
Soybean meal (44%)	22.32	22.32	22.32	22.32	22.32
Alfalfa meal (17%)	3.00	3.00	3.00	3.00	3.00
Tricalcium phosphate	2.30	2.30	2.30	2.30	2.30
Limestone	4.25	4.25	4.25	4.25	4.25
Salt	0.50	0.50	0.50	0.50	0.50
Premix, M5[1]	0.36	0.36	0.36	0.36	0.36
DL-Methionine	0.21	0.21	0.21	0.21	0.21
Total	100.00	100.00	100.00	100.00	100.00
Calculated analysis					
kcal ME/kg	2576	2682	2788	2894	3000
Protein, %	16	16	16	16	16
Energy:protein ratio[2]	161	168	174	181	188

[1] Provided the following per kg diet: vitamin A, 7900 I.U.; vitamin D_3, 2378 I.C.U.; vitamin E, 1.58 I.U.; riboflavin, 6.3 mg; d-calcium pantothenate, 8.7 mg; niacin, 29 mg; choline chloride, 317 mg; vitamin B_{12}, 0.009 mg; ethoxyquin, 0.59 mg; B.H.T., 179 mg; menadione, 1.59 mg; manganese, 86 mg; iron, 29 mg; copper, 2.9 mg; cobalt, 0.28 mg; and zinc, 39.6 mg.
[2] Based on kcal ME/kg diet.

ual maturity, egg weight, egg production, and feed, protein, and energy consumption. The data were statistically analyzed according to Duncan's multiple range test (1955) and Snedecor and Cochran's analysis of variance (1967).

RESULTS AND DISCUSSION

Effect of Dietary Energy Level

Body Weight and Gain

Table 2 shows that dietary energy significantly affected body weight. At 74 weeks of age the birds fed the 2894 kcal ME/kg diet weighed significantly more than those fed the 2576, 2682, and 2788

Table 2. Effect of dietary energy on body weight, body weight gain, mortality, and sexual maturity[1]

Parameter	Diet (kcal ME/kg) 1 (2576)	2 (2682)	3 (2788)	4 (2894)	5 (3000)
Body weight, g					
74 weeks	1591a	1603a	1596a	1781b	1660ab
Body weight gain, g[2]					
34 weeks	181a	165a	194a	225a	169a
58 weeks	219a	218a	254a	333a	261a
74 weeks	272a	294a	304a	400b	335ab
Mortality, %					
34 weeks	10.00a	6.00a	2.00a	6.00a	2.00a
58 weeks	12.00a	10.00a	6.00a	10.00a	10.00a
74 weeks	14.00a	12.00a	8.00a	18.00a	16.00a
Sexual maturity					
Age, 50% production, days	160.70	163.40	163.90	160.40	162.10

[1] Means on the same horizontal line bearing different letters are significantly different ($P < 0.05$).
[2] Attained weight minus 20-week initial weight.

kcal ME/kg diets. Those fed the 2894 and 3000 kcal ME/kg diets did not significantly differ in body weight.

Body weight gain at 34 and at 58 weeks of age was not significantly affected by dietary energy level. At 74 weeks of age, however, dietary energy level significantly affected weight gain. Pullets fed the 2894 kcal ME/kg diet gained significantly more weight than those fed the 2576, 2682, and 2788 kcal ME/kg diets. Those fed the 2576, 2682, 2788, and 3000 kcal ME/kg diets were similar in body weight gain. Pullets fed the dietary energy levels ranging from 2576 to 2894 kcal ME/kg diet increased their weight gains with increase in dietary energy (Table 2).

Mortality and Sexual Maturity

Table 2 also shows that mortality at 34, 58, and 74 weeks of age was not significantly affected by dietary energy. Mortality ranged from 8 to 18 percent at the end of the experiment.

Dietary energy level did not significantly affect sexual maturity. Age at 50 percent egg production ranged from 160.40 to 163.90 days (Table 2).

Egg Weight

Table 3 shows the data obtained on egg weight. Dietary energy level did not significantly affect egg weight from 22 to 28 weeks of age. Pullets fed the higher energy concentrations tended to lay heavier eggs; birds fed the 2894 kcal ME/kg diet tended to lay heavier eggs than those fed the 2576, 2682, and 2788 kcal ME/kg diets.

From 30 to 62 weeks of age, dietary energy level significantly affected egg weight. At 30 weeks, pullets fed the 2894 and 3000 kcal ME/kg diets produced significantly heavier eggs than those fed the 2682 kcal ME/kg diet. During the 30 to 62 week laying period, there was a trend toward increasing egg weight with increase in dietary energy.

According to the preceding data, it is suggested that the level of energy conducive to the production of optimum egg weight is 2894 kcal ME/kg when the dietary protein level is 16 percent. The data further reveal that as low as 2576 kcal ME/kg in the diet may be used

Table 3. Effect of dietary energy on egg weight[1]

	Diet (kcal ME/kg)				
Age, weeks	1 (2576)	2 (2682)	3 (2788)	4 (2894)	5 (3000)
	g	*g*	*g*	*g*	*g*
22	39.74a	40.72a	39.76a	41.08a	41.04a
23	43.76a	43.96a	43.14a	43.94a	44.58a
24	46.18a	45.36a	45.06a	46.16a	45.14a
25	47.72a	47.60a	47.38a	48.68a	47.90a
26	49.66a	48.58a	50.08a	50.14a	49.60a
27	50.96a	50.66a	51.40a	51.46a	50.88a
28	52.24a	51.64a	52.42a	52.90a	52.00a
30	53.50ab	53.22a	53.90ab	54.80b	53.96b
38	56.34a	56.56a	56.74ab	58.20ab	57.76b
46	57.80a	57.28a	58.22a	58.78a	59.24a
54	59.84a	59.62a	61.92b	61.64b	62.06b
62	61.68ab	60.20a	62.18ab	62.38ab	62.70b
22-28 week average	47.01a	47.83a	46.63a	47.51a	47.54a
22-62 week average	53.25a	52.93a	54.99a	54.21a	54.15a
30-62 week average	57.97ab	57.74a	58.97ab	59.58b	59.38ab

[1]Means on the same horizontal line bearing different letters are significantly different ($P < 0.05$).

without significantly affecting egg weight from 22 to 28 weeks of age. On the other hand, as the pullets grow older after 28 weeks of age, the dietary level for the production of optimum egg weight is 2894 kcal ME/kg (energy to protein ratio, 181).

The preceding observations on egg weight agree with those of Hochreich et al. (1958), Treat et al. (1960), Blamberg et al. (1964), and Jackson et al. (1969), who reported that the addition of fat to the layer diets increased egg weight, but are at variance with MacIntyre and Aitken (1957) and Lillie and Denton (1965), who noted that the addition of 10 percent tallow in the layer diet significantly decreased egg weight when compared with isocaloric diets containing 0 to 5 percent tallow. MacIntyre and Aitken and Lillie and Denton suggested that supplementary fat per se did not seem to affect egg size but that feed intake appeared to be the causative factor.

Egg Production

Egg production data may be seen in Table 4. Dietary energy levels ranging from 2576 to 3000 kcal ME/kg did not significantly affect egg

Table 4. Effect of dietary energy on hen-day egg production[1]

	Diet (kcal ME/kg)				
Age, weeks	1 (2576)	2 (2682)	3 (2788)	4 (2894)	5 (3000)
	%	%	%	%	%
22–26	49.14a	45.71a	44.84a	51.53a	50.14a
26–30	73.52a	75.81a	73.93a	75.41a	72.47a
30–34	64.91a	65.73a	66.10a	66.34a	64.03a
34–38	71.27b	72.92b	70.44ab	73.72b	65.81a
38–42	67.05a	73.87b	69.79ab	73.45ab	71.12ab
42–46	55.49a	65.03b	61.98ab	68.25b	65.96b
46–50	55.44ab	58.70ab	55.40ab	63.01b	49.78a
50–54	56.48a	62.72ab	64.27ab	66.11b	56.23a
54–58	55.10a	65.51b	64.26b	68.17b	65.72b
58–62	62.87a	68.20a	65.34a	65.71a	64.06a
62–66	65.39a	66.90a	62.15a	65.65a	63.43a
66–70	62.26a	62.15a	58.79a	63.34a	60.85a
70–74	58.44a	60.21a	57.49a	63.95a	56.14a
22–74 week average	61.34a	63.12ab	62.68ab	66.51b	61.98ab

[1] Means on the same horizontal line bearing different letters are significantly different ($P < 0.05$).

production from 22 to 34 weeks and from 58 to 74 weeks of age; however, dietary energy significantly affected egg production from 34 to 58 weeks of age. The data also show that during the 22 to 74 weeks test period, dietary energy significantly affected average egg production. Pullets fed the 2894 kcal ME/kg diet produced the most eggs—and significantly more eggs (66.51 percent) than those fed the 2576 kcal ME/kg diet (61.34 percent). Birds fed the 2576 kcal ME/kg diet did not significantly differ in egg production from those fed the 2682, 2788, and 3000 kcal ME/kg diets. According to the preceding data, under the conditions of this experiment, it is suggested that 2894 kcal ME/kg in the layer diet is optimum for egg production.

Data obtained on egg production in this study are consistent with those of Skinner et al. (1951), Hill et al. (1956), and Waring et al. (1968), who found that high-energy diets support high egg production, but are at variance with those of Lillie and Denton (1965), who reported that energy level in the diet did not significantly affect egg production.

Feed Consumption and Efficiency

Table 5 shows that dietary energy level significantly affected feed consumption. From 22 to 74 weeks of age, pullets fed the 2576 and 2682 kcal ME/kg diets consumed similar amounts of feed daily but significantly more than those fed the 2788, 2894, and 3000 kcal ME/kg diets. Pullets fed the 2788 kcal ME/kg consumed significantly less feed than those fed the 2894 kcal ME/kg diet but significantly more than those fed the 3000 kcal ME/kg diet. The data also show that feed consumption tends to decrease with increase in dietary energy.

Feed efficiency was also significantly affected by the level of energy in the diet. Pullets fed the 2894 and 3000 kcal ME/kg diets consumed similar amounts of feed per egg produced, but significantly less than those fed the two lowest dietary energy diets (2576 and 2682 kcal ME/kg), which were not significantly different from each other. The amount of feed consumed per egg produced decreased with increase in dietary energy.

The foregoing data agree with those of Singsen et al. (1952), Grimminger and Scott (1954), Hill (1956), Anderson et al. (1957), and Jackson et al. (1969), who reported that diets containing low concentrations of energy are less efficient than those with high energy.

Table 5. Effect of dietary energy on feed, protein, and energy consumption from 22 to 74 weeks of age[1]

Consumption	Diet (kcal ME/kg) 1 (2576)	2 (2682)	3 (2788)	4 (2894)	5 (3000)
Feed/bird/day, g	99.22d	97.05d	94.40b	95.00c	88.14a
Feed/egg, g	162.02b	155.02b	150.42ab	142.80a	142.54a
Protein/bird/day, g	15.87c	15.53bc	15.12b	15.20ab	14.10a
Protein/egg, g	25.92a	24.88a	24.13a	26.71a	22.81a
ME/bird/day, kcal	255.62a	260.32ab	266.94ab	282.28b	264.40a
ME/egg, kcal	417.36a	417.08a	426.02a	437.80a	427.64a

[1] Means on the same horizontal line bearing different letters are significantly different ($P < 0.05$).

Protein Consumption and Efficiency

Treatment significantly affected protein intake. This was expected in view of the linear negative relationship between caloric content of the diet and feed consumption. Pullets fed the 3000 kcal ME/kg diet consumed significantly less protein than those fed the 2576, 2682, and 2788 kcal ME/kg diets (Table 5). Those fed the 2788 and 2894 kcal ME/kg diets consumed similar amounts of protein but significantly less protein than those fed the 2576 kcal ME/kg diet. Those fed the 2682 and 2894 kcal ME/kg diets were not significantly different. Protein consumption tended to decrease with increase in dietary energy.

The data in Table 5 show that dietary energy level did not significantly affect the amount of feed required to produce a unit of egg. Protein efficiency ranged from 22.81 to 26.71 g. Pullets fed the 3000 kcal ME/kg diet consumed the least amount of protein (22.81 g) per egg produced. Those fed the 2894 kcal ME/kg diet consumed the most protein (26.71 g) per egg and produced the greatest number of eggs.

The preceding data are comparable to published information. The National Academy of Sciences (1971) reported that White Leghorn pullets laying at a rate of 60 percent and weighing 1800 g require 16.0 g protein daily. The birds used in the present experiment were smaller and consumed from 14.1 to 16.1 g protein daily, depending on the caloric content of the diet. Scott et al. (1969) noted that, under warm environmental conditions, protein requirement of White Leghorn pullets was 16.0 g daily when the diet contained 2800 kcal ME/kg.

Energy Consumption and Efficiency

Dietary energy level significantly affected energy consumption. Pullets fed the 2894 kcal ME/kg diet consumed significantly more energy than those fed the 2576 and 3000 kcal ME/kg diets (Table 5). Those fed the 2576, 2682, 2788, and 3000 kcal ME/kg diets did not significantly differ in energy consumption. Consumption of energy increased with increase in the energy content of the diet from 2576 to 2894 kcal ME/kg. It was noted that energy consumption decreased when the dietary energy content of the diet was 3000 kcal ME/kg. According to the preceding data, it is suggested that there may be an upper limit of dietary energy that is conducive to the linear relationship of energy consumption and energy concentration in the diet.

The amount of energy consumed per egg produced was not significantly affected by dietary energy level. However, there was a trend toward increasing amounts of energy consumption per egg produced when the birds were fed diets containing 2576 to 2894 kcal ME/kg. Pullets fed the 3000 kcal ME/kg diet consumed less energy (10.16 kcal ME/kg) per egg produced than those fed the 2894 kcal ME/kg diet.

The preceding observations corroborate those of Jackson et al. (1969), who reported that daily metabolizable energy intake increases with increase in dietary energy, but are at variance with the suggestion of Hill (1962) that the highly productive hen consumes approximately 350 kcal of metabolizable energy daily. Pullets used in this study consumed from 255.62 to 282.28 kcal of metabolizable energy per day.

Effect of Seasonal Temperature

Egg Production

Seasonal temperature changes, even under the normally mild Hawaii conditions, significantly affected hen-day egg production (Table 6). During the colder months of December to April (period 2), when

Table 6. Effect of dietary energy on seasonal egg production and feed, protein, and energy consumption[1,2]

Parameter	Diet (kcal ME/kg) 1 (2576)	2 (2682)	3 (2788)	4 (2894)	5 (3000)
Hen-day egg production, %					
22–38 weeks	64.71a	65.04a	63.83a	66.81a	63.11a
38–58 weeks	57.91a	65.18bc	63.14abc	67.80c	61.76ab
58–74 weeks	62.24a	64.37a	60.94a	64.66a	61.12a
Feed/bird/day, g					
22–38 weeks	87.65c	84.23bc	81.92b	82.22b	76.20a
38–58 weeks	103.26b	101.97b	98.68b	100.69b	91.84a
58–74 weeks	106.16c	103.74bc	101.80bc	100.67b	95.45a
Protein/bird/day, g					
22–38 weeks	14.02c	13.48bc	13.11b	13.15b	12.19a
38–58 weeks	16.52b	16.31ab	15.79ab	16.11ab	14.69a
58–74 weeks	16.99b	16.60ab	16.29ab	16.11ab	15.27a
ME/bird/day, kcal					
22–38 weeks	255.78a	255.84a	228.40ab	237.96b	228.58a
38–58 weeks	265.98a	273.48a	275.38a	291.42b	275.20a
58–74 weeks	273.44a	278.22ab	283.82abc	291.34c	286.90bc

[1] Means on the same horizontal line bearing different letters are significantly different ($P < 0.05$).

[2] Period	Age, weeks	Date	Temperature, °C Low	High
1	22–38	8 August–10 December	23.2	29.1
2	38–58	10 December–29 April	19.1	24.6
3	58–74	29 April–19 August	21.1	28.2

the average daily minimum temperature was 19.1°C and the average maximum temperature was 24.6°C, pullets fed the diet containing 2576 kcal ME/kg produced significantly fewer eggs than those fed the 2682 and 2894 kcal ME/kg diets and produced from 3.85 to 9.89 percent fewer eggs than those fed diets containing 2682 to 3000 kcal ME/kg. During the warmer months of August to December (period 1: 23.2–29.1°C) and April to August (period 3: 21.1–28.2°C), pullets fed diets containing 2576 to 3000 kcal ME/kg produced similar numbers of eggs. There were 4 days when the maximum temperature reached 32.2°C or over during the experiment. The maximum temperature was 35.6°C and the minimum temperature 15.6°C. Daily extremes of relative humidity ranged from 40 to 90 percent.

The reason that birds fed the 2576 kcal ME/kg diet produced significantly fewer eggs than those fed the other diets containing higher concentrations of energy during the colder but not the warmer months may be explained in part in terms of energy consumption. It can be seen in Table 5 that birds fed the 2576 kcal ME/kg diet consumed significantly less total energy, although they consumed greater amounts of feed, than those fed the 2682 to 3000 kcal ME/kg diets. During the colder months of period 2, the dietary energy concentration of 2576 kcal ME/kg may not have been sufficient to meet the requirement for both maintenance and optimum egg production.

Feed Consumption

Table 6 shows that dietary energy significantly affected feed consumption during both the warmer months (periods 1 and 3) and the colder months (period 2). From 22 to 38 weeks of age, feed consumption ranged from 76.20 to 87.65 g per bird daily. Pullets fed the 3000 kcal ME/kg diet consumed significantly less feed than those fed the 2576 to 2894 kcal ME/kg diets. Birds fed the diet containing the lowest energy (2576 kcal ME/kg) consumed the most feed (87.65 g) daily.

During the colder months (period 2), when the birds were 38 to 58 weeks of age, dietary energy significantly affected daily feed consumption. Birds fed the 3000 kcal ME/kg diet consumed significantly less than those fed the 2576 to 2894 kcal ME/kg diets, which were not significantly different in feed consumption. Average feed consumption during this period ranged from 91.84 to 103.26 g per bird daily.

Dietary energy also significantly affected feed consumption during the warmer months of period 3 when the birds were 58 to 74 weeks of age. As in both periods 1 and 2, daily feed consumption of the birds fed the diet containing the highest energy (3000 kcal ME/kg) consumed significantly less feed than those fed the diets containing the lower concentrations of energy (2576 to 2894 kcal ME/kg). The data in Table 5 also show that daily feed consumption decreases with increase in the concentration of energy in the diet.

Protein Consumption

Dietary energy level significantly affected protein consumption during both the warmer months of periods 1 and 3 and the colder months of period 2 (Table 6). From 22 to 38 weeks of age (period 1), protein consumption of birds fed the 3000 kcal ME/kg diet consumed significantly less protein than those fed the 2576 to 2894 kcal ME/kg diets. Those fed the 2682 and 2894 kcal ME/kg diets consumed significantly less protein than those fed the 2576 kcal ME/kg diet.

From 38 to 58 weeks of age (period 2), protein consumption was significantly affected by dietary energy concentration. Pullets fed the 3000 kcal ME/kg diet consumed significantly less protein than those fed the 2576 kcal ME/kg diet, whereas those fed the 2682 to 2894 kcal ME/kg diets consumed similar amounts of protein daily.

During period 3 (58 to 74 weeks of age), protein consumption was significantly affected by the energy concentration in the diet. Pullets fed the highest concentration of energy (3000 kcal ME/kg) consumed significantly less protein than those fed the 2576 kcal ME/kg diet. Those fed the 2576 to 2894 kcal ME/kg diets consumed similar amounts of protein daily. Protein consumption during this period ranged from 15.27 to 16.99 g daily.

Energy Consumption

Table 6 also shows that dietary energy level significantly affected caloric intake during both the warmer months (periods 1 and 3) and the colder months (period 2). From 22 to 38 weeks of age (period 1), energy consumption ranged from 255.78 to 237.96 kcal ME/kg daily. Pullets fed the lowest dietary energy (2576 kcal ME/kg) consumed the least energy, whereas those fed the 2894 kcal ME/kg diet consumed the most. Those fed the 2576, 2682, 2788, and 3000 kcal ME/kg diets consumed similar amounts of energy.

From 38 to 58 weeks of age (period 2), dietary energy also significantly affected caloric consumption. Pullets fed the 2894 kcal ME/kg diet consumed significantly more energy than those fed the 2576, 2682, 2788, and 3000 kcal ME/kg diets.

From 58 to 74 weeks of age (period 3), as in periods 1 and 2, energy consumption was significantly affected by dietary energy concentration. Caloric intake increased with increase in dietary energy. The range was from 273.44 to 291.34 kcal ME/kg. Pullets fed the 2576 kcal ME/kg diet consumed significantly less energy than those fed the 2894 and 3000 kcal ME/kg diets. Those fed the 2788, 2894, and 3000 kcal ME/kg diets consumed similar amounts of dietary energy.

The preceding data are comparable to those of Francis et al. (1972), who found that energy needs of chickens become greater at lower temperatures and that more efficient production can be anticipated in climatic or housing conditions in temperatures ranging from 80 to 88°F.

Feed Efficiency

Table 7 shows that dietary energy significantly affected the amount of feed consumed per egg produced in period 1 (22 to 38 weeks). During this warmer period, the feed consumption per egg ranged from 121.40 to 135.72 g. Feed consumption per egg decreased with increase in dietary energy. Pullets fed the 3000 kcal ME/kg diet consumed significantly less feed per egg than those fed the 2576 kcal ME/kg diets. The birds fed the lowest energy concentration (2576 kcal ME/kg) were the least efficient.

Table 7. Effect of dietary energy on seasonal feed, protein, and energy efficiency[1, 2]

	Diet (kcal ME/kg)				
Consumption	**1 (2576)**	**2 (2682)**	**3 (2788)**	**4 (2894)**	**5 (3000)**
Feed/egg, g					
22-38 weeks	135.72c	129.78bc	128.80bc	123.06b	121.40a
38-58 weeks	178.96b	156.56a	156.34a	148.86a	149.06a
58-74 weeks	171.48a	161.92a	167.82a	155.86a	158.44a
Protein/egg, g					
22-38 weeks	21.72b	20.77ab	20.61ab	19.68a	19.42a
38-58 weeks	28.63b	25.05a	25.01a	23.82a	23.85a
58-74 weeks	27.44a	25.91a	26.86a	24.94a	25.35a
ME/egg, kcal					
22-38 weeks	349.62a	347.98a	359.28a	356.22a	364.16a
38-58 weeks	460.92b	419.90a	436.30ab	430.78ab	447.20a
58-74 weeks	441.66a	434.28a	467.96a	451.04a	476.06a

[1] Means on the same horizontal line bearing different letters are significantly different ($P < 0.05$).

[2] Period	Age, weeks	Date	Temperature, °C Low	Temperature, °C High
1	22-38	8 August-10 December	23.2	29.1
2	38-58	10 December-29 April	19.1	24.6
3	58-74	29 April-19 August	21.1	28.2

During the colder months of period 2 (38 to 58 weeks), feed consumption per egg ranged from 148.86 to 178.96 g. Pullets fed the 2576 kcal ME/kg diet were the least efficient and significantly inferior to those fed the 2682 to 3000 kcal ME/kg diets, which were not significantly different from each other.

During the warmer months of period 3 (58 to 78 weeks of age), dietary energy did not significantly affect feed efficiency. Feed consumption per egg ranged from 155.86 to 171.48 g.

Protein Efficiency

The amount of protein consumed per egg produced in period 1 decreased as concentration of energy in the diet was increased. Pullets fed the 2576 kcal ME/kg diet consumed significantly more protein per egg than those fed the 2894 and 3000 kcal ME/kg diets. Birds fed the 2682 to 3000 kcal ME/kg diets were not significantly different in protein efficiency.

During the colder months of period 2 (38 to 58 weeks), protein efficiency was also significantly affected by dietary energy. Pullets fed the 2576 kcal ME/kg diet consumed significantly more protein than those fed the 2682 to 3000 kcal ME/kg diets, which were similar in protein efficiency.

During the warmer months (period 3), no significant effect of dietary energy on protein efficiency was observed. Pullets consumed 24.94 to 27.44 g protein per egg produced. Those fed the 2576 kcal ME/kg diet were the least efficient, while those fed the 3000 kcal ME/kg diet were the most efficient.

Energy Efficiency

In Table 7, it may be seen that energy consumption per egg produced from 22 to 38 weeks of age (period 1) ranged from 347.98 to 364.16 kcal ME/kg. Dietary energy did not significantly affect energy consumption per egg. During the colder months of period 2 (December–April), however, dietary energy concentration significantly affected the amount of feed consumed per egg. Pullets fed the 2576 kcal ME/kg diet consumed significantly more energy per egg than those fed the 2682 and 3000 kcal ME/kg diets. Those fed the 2894 kcal ME/kg diet were the most efficient (430.78 kcal ME/egg).

During the warmer months of period 3 (April–August), dietary energy did not significantly affect the amount of feed consumed per egg produced. During this period, energy efficiency ranged from 434.28 to 476.06 g. The most efficient converters of dietary energy were the birds fed the 2682 kcal ME/kg diet; the least efficient were those fed the 3000 kcal ME/kg diet.

According to the preceding data, 2576 to 3000 kcal ME/kg diets may be fed to laying White Leghorn pullets during the warmer months of August to December (period 1: 23.2–29.1°C) and April to August (period 3: 21.1–28.2°C) without significantly affecting overall feed efficiency, but not during the colder months of December to April (period 2: 19.1–24.6°C). The 2576 kcal ME/kg diet provided inadequate energy for optimum overall efficiency of egg production during the colder months, whereas the same diet was adequate during the warmer months. These observations are in agreement with those of Francis et al. (1972). They found that at lower temperatures chickens require greater amounts of energy. During the colder months, pullets fed the 2576 kcal and 2682 kcal ME/kg diets consumed significantly more feed per egg than those fed the 2894 kcal and 3000 kcal ME/kg diets (Table 5). Those fed the 3000 kcal ME/kg diet produced fewer eggs than those fed the 2894 kcal ME/kg diet during both the warmer and colder months (Table 6).

CONCLUSIONS

Under the normally mild temperature conditions of Hawaii, the optimum dietary energy level for egg production is 2894 kilocalories of metabolizable energy per kilogram (kcal ME/kg) of diet when the protein content is 16 percent. During the colder months of December to April, feed efficiency of pullets fed a diet of 2576 kcal ME/kg is significantly inferior to that of pullets fed diets of 2682 to 3000 kcal ME/kg, which are not significantly different from each other.

LITERATURE CITED

Anderson, G.J., C.F. Petersen, A.C. Wiese, and C.E. Lampman. 1957. The effect of high vitamin supplementation of high and low energy rations on egg production and egg shell quality. Poultry Sci. 36:1369-1376.

Blamberg, D.L., E.H. Bossard, and G.F. Combs. 1964. Influence of energy intake on egg weight with diets varying in fat content and physical form. Poultry Sci. 43:1304.

Brown, W.P. 1964. High energy diets for poultry. London Tech. Pub., U.S. Feed Grain Council, and U.S. Dep. Agr. Foreign Agr. Service.

Duncan, D.B. 1955. Multiple range and multiple F tests. Biometrics 11:1-42.

Francis, D.W., B.L. Reid, and W.O. Wilson. 1972. Effects of atmospheric stresses on the performances of poultry. New Mexico Agr. Exp. Sta. Bull. 601.

Griminger, P., and H.M. Scott. 1954. The effect of different cereals on feed efficiency, egg quality, and shell thickness. Poultry Sci. 33:1217-1219.

Hill, F.W. 1956. Studies of the energy requirements of chickens. 4. Evidence for a linear relationship between dietary productive energy level and the efficiency of egg production. Poultry Sci. 35:59-63.

Hill, F.W. 1962. Some aspects of the physiology of food intake and digestion in chickens. J.T. Morgan and D. Lewis, eds., Nutrition of pigs and poultry. Butterworth, London.

Hill, F.W., D.L. Anderson, and L.M. Dansky. 1956. Studies of the energy requirements of chickens. 3. The effect of dietary energy level on the rate and gross efficiency of egg production. Poultry Sci. 37:949-953.

Hochreich, H.J., C.R. Douglas, I.H. Kidd, and R.H. Harms. 1958. The effect of dietary protein and energy levels upon production of Single Comb White Leghorn hens. Poultry Sci. 37:949-953.

Jackson, N., H.R. Kirkpatrick, and R.B. Fulton. 1969. An experimental study of the utilization by the laying hen of dietary energy partially supplied as animal fat. British Poultry Sci. 10:115-126.

Lillie, R.J., and C.A. Denton. 1965. Protein and energy interrelationships for laying hens. Poultry Sci. 44:753-761.

Lillie, R.J., J.R. Sizemore, J.L. Milligan, and H.R. Bird. 1952. Thyroprotein and fat in laying hens. Poultry Sci. 31:1037-1042.

MacIntyre, T.M., and J.R. Aitken. 1957. The effect of high levels of dietary energy and protein on the performance of laying hens. Poultry Sci. 36:1211-1216.

March, B.E., and J. Biely. 1963. The effects of dietary fat and energy levels on the performance of caged laying birds. Poultry Sci. 42:20-24.

National Academy of Sciences. 1971. 1. Nutrient requirements of poultry. 6th revised edition. Washington, D.C. Publication 1345.

Scott, H.M., L.D. Matterson, and E.P. Singsen. 1947. Nutritional factors influencing growth and efficiency of feed utilization. 1. The effect of source of carbohydrate. Poultry Sci. 26:554.

Scott, M.L., M.C. Nesheim, and R.J. Young. 1969. Nutrition of the chicken. M.L. Scott and Associates, Ithaca, New York.

Singsen, E.P., L.D. Matterson, and A. Kozeff. 1952. A high-efficiency ration for laying and breeding hens. Storrs (Connecticut) Agr. Exp. Sta. Bull. 286.

Skinner, J.L., J.H. Quisenberry, and J.R. Couch. 1951. High efficiency and APF concentrates in the ration of the laying fowl. Poultry Sci. 30:319–324.

Snedecor, G.W., and W.G. Cochran. 1967. Statistical methods, 6th ed. Iowa State University Press, Ames, Iowa.

Treat, C.M., B.L. Reid, R.E. Davies, and J.R. Couch. 1960. The effect of animal fat and mixtures of animal fatty acids on performance of cage layers. Poultry Sci. 39:1550–1555.

Waring, J.J., R.F. Addison, and W.O. Brown. 1968. A comparative study of energy utilization by the laying hen from diets containing a high proportion of fat and diets made up mainly from carbohydrate source. British Poultry Sci. 9:79–86.

UNIVERSITY OF HAWAII
COLLEGE OF TROPICAL AGRICULTURE
HAWAII AGRICULTURAL EXPERIMENT STATION
HONOLULU, HAWAII

THOMAS H. HAMILTON
President of the University

MORTON M. ROSENBERG
Dean of the College and
Director of the Experiment Station

G. DONALD SHERMAN
Associate Director of the Experiment Station